PERFORMANCE ANALYSIS OF REACTIVE ROUTING PROTOCOL BASED ON LESS-FLOODING AODV AND ROUTE STABILITY AWARE IN MOBILE AD-HOC NETWORKS

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ABSTRACT

The objective of this study is to propose a practical solution to help improve the performance of the routing discovery process in Mobile Ad-hoc Networks (MANETs). The study involved the development of two new routing protocols, namely Less-Flooding Ad-hoc On-demand Distance Vector (LF-AODV) and Route Stability Aware (RSA) protocols, with the aim of reducing the number of transmitted route request (RREQ) packets and link failures during the route discovery cycle. Accordingly, a series of simulations carried out with the NS-2 simulator to examine the performance of such new protocols for 100 mobile nodes in an area measuring 600 meters x 600 meters. The performance criteria were based on routing overhead (the total number of packets transmitted by a source node during the route discovery process), average end-to-end delay (the average time taken by a packet to arrive at a destination node from a source node), and network lifetime (time taken until all nodes in a network die due to battery exhaustion). The simulation results showed that the RSA protocol managed to reduce the total overheads by 14% and 11%, and delays by 29% and 21% with respect to the AODV and LF-AODV protocols, respectively. Furthermore, the RSA protocol was able to increase the network lifetime by 12% and 8% compared to those of the AODV and LF-AODV protocols, respectively. Such findings suggest that the RSA protocol can help improve the performance of MANETs by making such networks more stable and reliable. Clearly, such research findings will have a profound implication on the current practice of practitioners in the network industry, notably service providers and mobile network operators, who can use the RSA protocol to improve the quality of their products or services. With the use of more efficient, stable MANETs, end users will be able to use mobile applications anywhere, anytime more reliably, resulting in higher user satisfaction that benefits all concerned.

ANALISIS PRESTASI PROTOKOL PENGHALAAN REAKTIF BERDASARKAN *LESS-FLOODING AODV* DAN *ROUTE STABILITY AWARE* DALAM RANGKAIAN *AD-HOC* MUDAH ALIH

ABSTRAK

Objektif kajian ini adalah untuk mencadangkan satu penyelesaian yang praktikal untuk meningkatkan prestasi proses pencarian laluan dalam rangkaian ad hoc mudah alih (MANETs). Kajian ini melibatkan pembangunan dua protokol penghalaan baru, iaitu protokol *Less-Flooding Ad-hoc On-Demand Distance Vector* (LF-AODV) dan protokol *Route Stability Aware* (RSA), yang bertujuan untuk mengurangkan bilangan paket permintaan laluan (RREQ) yang dihantar, dan kegagalan sambungan sepanjang kitaran pencarian laluan. Oleh itu, satu siri simulasi telah dijalankan dengan pensimulasi NS-2 untuk menilai prestasi protokol baru berkenaan untuk 100 nod bergerak dalam kawasan berukuran 600 meter x 600 meter. Kriteria pengukuran prestasi adalah berdasarkan overhed penghalaan (jumlah paket yang dihantar nod sumber sepanjang proses pencarian laluan), purata kelewatan hujung-ke-hujung (purata masa yang diambil oleh paket untuk sampai ke nod destinasi dari nod sumber), dan jangka hayat rangkaian (masa yang diambil sehingga semua nod dalam rangkaian tidak dapat berfungsi kerana kehabisan bateri). Hasil simulasi menunjukkan protokol RSA dapat mengurangkan overhed penghalaan sebanyak 14% dan 11%, dan kelewatan sebanyak 29% dan 21% berbanding protokol AODV dan LF-AODV. Selanjutnya, protokol RSA dapat meningkatkan jangka hayat rangkaian sebanyak 12% dan 8% berbanding protokol AODV dan LF-AODV. Dapatan ini menunjukkan protokol RSA boleh meningkatkan prestasi MANETs dengan menjadikan rangkaian tersebut lebih stabil dan boleh dipercayai. Jelas sekali, dapatan kajian ini mempunyai satu implikasi yang mendalam terhadap amalan semasa para pengamal dalam industri rangkaian, terutama penyedia perkhidmatan dan pengendali rangkaian bergerak, di mana mereka dapat menggunakan protokol RSA untuk meningkatkan kualiti produk dan perkhidmatan mereka. Dengan penggunaan MANETs yang lebih efisyen dan stabil, para pengguna dapat menggunakan aplikasi bergerak di mana-mana dan pada bila-bila masa yang dapat menghasilkan kepuasan pengguna yang lebih baik dan seterusnya memberi pelbagai faedah kepada semua yang terlibat.

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LIST OF ABBREVIATIONS

AODV	Ad hoc On Demand Distance Vector
AP	Access Point
BS	Base Station
CBR	Constant Bit Rate
CMMBCR	Conditional Maximum Battery Capacity Routing
DSDV	Destination-Sequenced Distance-Vector
DSR	Dynamic Source Routing
EAODV	Energy-Aware AODV
GLOMOSIM	Global Mobile Information Systems Simulation Library
I-AODV	Improved AODV
ID	Identification
IEEE	The Institute of Electrical and Electronic Engineers
IP	Internet Protocol
LF-AODV	Less Flooding AODV
LLT	Link Life Time
LSEA	Link Stability Energy Aware
MAC	Medium Access Control
MANET	Mobile Ad hoc Network
MBCR	Minimum Battery Cost Routing

MMBCR	Max-Min Battery Cost Routing
MP3	MPEG Audio Layer-3
MPR	Multipoint Relay
MPRAODV	Multi Point Relay AODV
MTPR	Minimum Total Transmission Power Routing
MRAODV	Modified Reverse AODV
NAM	Network Animator
NAODV	New AODV
NLSEA-AODV	Novel Link Stability and Energy Aware Routing for MANET
NS-2	Network Simulator-2
OLSR	Optimized Link State Routing
OS	Operating System
OTCL	Object Oriented TCL
OPNET	Optimized Network Engineering Tool
OMNET++	Objective Modular Network Test bed in C++
PDA	Personal Digital Assistant
PDR	Packet Delivery Ratio
R-AODV	Reverse AODV
RE	Residual Energy
RO	Routing Overhead
RO-AODV	Route Optimized AODV
RPGM	Reference Point Group Mobility
RREP	Route Reply Packet

RREQ	Route Request Packet
RERR	Route Error
R-RREQ	Reverse RREQ
RSA	Route Stability Aware
RSEA-AODV	Route Stability and Energy Aware Routing for MANET
RWP	Random Way Point
SEAR-AODV	Stability and Energy Aware Reverse AODV
TC	Topology Control
TCL	Tool Command Language
TCP	Transmission Control Protocol
TTL	Time-To-Live
UDP	User Datagram Protocol

APPENDIX LIST

CHAPTER 1

INTRODUCTION

1.1 Background

Since their emergence in the 1970s, wireless networks have become increasingly popular in the computing industry. This is particularly true in the recent decades as wireless networks have been successfully employed by many industries to improve mobility (Jayakumar & Gopinath, 2007; Singh et al., 2015). Currently, there are two categories of wireless networks, namely the infrastructure and mobile ad hoc networks (Maqbool & Peer, 2010; Helen & Arivazhagan, 2014; Senthilkumaran & Sankaranarayanan, 2013). Specifically, the infrastructure network refers to networks in which communication has to go through a base station or access points that act as a gateway between the wired and wireless domains. In contrast, the mobile ad hoc network refers to networks in which communication occurs without the existence of any fixed infrastructure or centralized administration (Lindgren & Schel´en, 2002;

Gowrishankar et al., 2010; Sarkar et al., 2016). Figure 1.1 shows an example of the architecture of the infrastructure and mobile ad hoc networks.

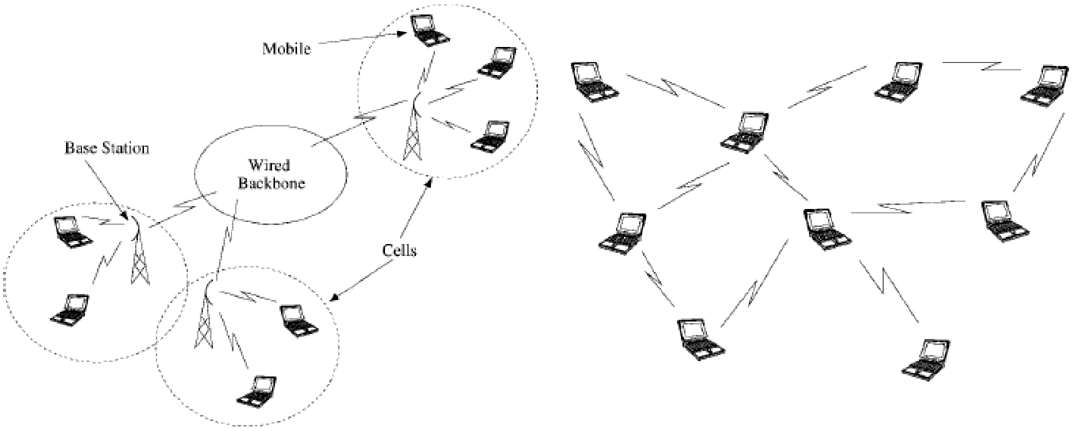

Figure 1.1. The architecture of the infrastructure and ad-hoc networks. Adapted from Jones et al., 2001

Lately, the use of mobile ad hoc networks (MANETs) has drastically changed the communication realm in which interactions among people are becoming more dynamic and fluid, making their works and lives more productive and entertaining, respectively. Arguably, such accomplishments owe to the strong connectivity accorded by MANETs. Of late, such networks have been making significant inroad in several fields of applications, as practitioners are beginning to realize the enormous potentials of MANETs in such fields. Specifically, MANETs are able to provide enhanced functional flexibility in 'on-demand' situations (Jhaveri & Patel, 2015), to transport a wide spectrum of applications, and to dynamically 'heal' failed network elements (Kant & Chadha, 2008). As such, MANETs are suitable to be deployed in areas in which existing fixed-backbone network infrastructures are inflexible and cumbersomely uneconomical (Ray & Turuk, 2016). Thus, it is not surprising to see such networks being largely used in specific applications, such as military (in battlefields), commerce (in disaster discovery systems, search-and-rescue operations, and e-commerce), and education (in conferences and conventions) (Shobha & Rajanikanth, 2011).

In principle, all participating nodes of a MANET need to share and exchange information efficiently through a stable connection (Back, 2005). However, as nodes in MANET are highly mobile, the connection between nodes is restricted by the network's wireless transmission range as two participating nodes can only communicate directly with each other if they are within the same transmission range (Dipobagio, 2009). Therefore, nodes that are not within the transmission range need support from intermediate nodes or devices to transmit and deliver the required data among the former nodes (Jasani, 2012). In this respect, a routing protocol plays an important role to maintain the connection among nodes in a network by establishing sound network communication to ensure smooth, uninterrupted flow of information or services (Nissar et al., 2015).

For example, in military applications, an army has to constantly rely on accurate, latest information about their enemy's location to enable them to react or to plan an effective strategic offensive (Back, 2005). Obviously, the more information available the better they will be able to make a better decision (Back, 2005). However, the connection between the combatants is unstable as they are free to move independently in any directions, thus allowing them to leave or connect to a network without restrictions (Dipobagio, 2009). In view of such instability, a routing protocol is essential to establish and maintain a stable connection among the army personnel that allows them to communicate and shares the latest information of their enemy's location without any interruptions.

Figure 1.2 shows a routing protocol of MANET applications to provide a number of services or information to several network users. As highlighted, when the source node requests a certain service 'A', it generates a discovery process to find such a service (represented by the black arrows in the figure) (Reina et al., 2013). The intermediate nodes retransmit the incoming request until it reaches the destination node, which is the element of the network that supplies the required service. In fact, the routing protocol will select the most appropriate route from among the several established routes during the discovery process (Reina et al., 2013).

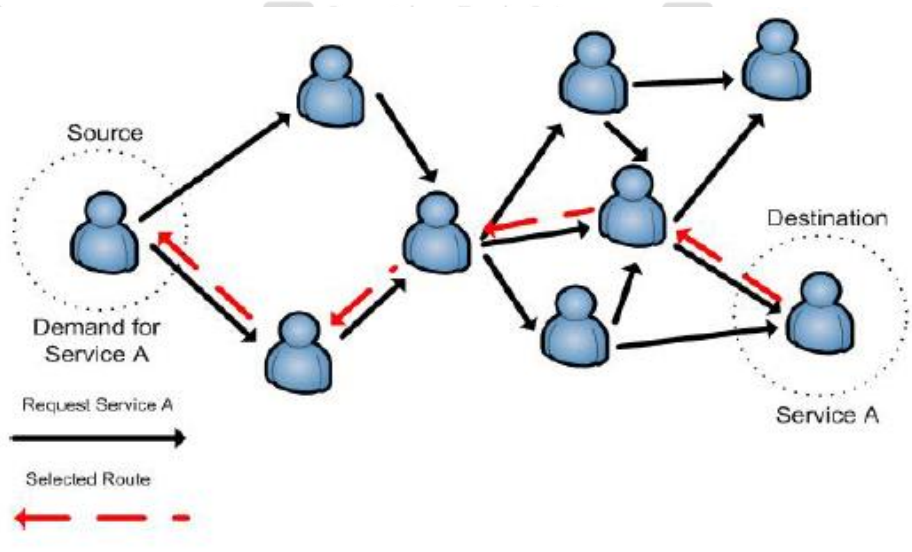

Figure 1.2. Routing protocols for MANET applications. Adapted from Reina et al., 2013

To date, various routing protocols have been developed for MANETs, such as OLSR (Optimized Link State Routing), DSDV (destination-sequence distance vector) (Adoni & Joshi, 2012; Li et al., 2012), DSR (Dynamic Source Routing) (Jasani, 2012; Khan et al., 2014), and AODV (Ad-hoc On-demand Distance Vector) (Jasani, 2012; Li et al., 2012) protocols. These protocols, which have been designed based on several different approaches, offer varying degrees of efficiency. For this research, the AODV (reactive) and OLSR (proactive) protocols were selected as the subjects of analysis due to their popularity and continually improving efficiency (Katiyar et al., 2015). In particular, the AODV protocol was selected for further investigation and analysis as the OLSR protocol produces relatively higher overheads (Katiyar et al., 2015). Furthermore, the selection of AODV was reinforced by its superior efficiency in low and high mobility networks and traffics compared to that of OLSR (Kaur, 2013).

1.2 Problem Statements

The AODV protocol will perform the route discovery process to maintain and generate stable paths among nodes in a network. In principle, this protocol performs the route discovery process by flooding the network with a route request (RREQ) packets (Vanthana & Prakash, 2014) as shown in Figure 1.2. However, flooding the entire nodes of the network with route request (RREQ) packets may lead to redundancy of request packets as a node will receive the same packets from multiple nodes (Yassein et al., 2006), thus incurring packet collisions that lead to poor performance of ad-hoc communications (Reina et al., 2013). In the computing realm, such a problem is widely known as the ‘broadcast storm’ (Tonguz et al., 2006; Tseng, et al., 2002).

Furthermore, AODV has to deal with the topological changes that occur during the route discovery process. Inevitably, such topological changes resulting from high mobility of nodes can make them constantly lose their energy (Latiff & Fisal, 2003). Eventually, the energy depletion will become so acute that it can cause frequent link failures and route breakages in MANETs (Fadaly et al., 2014). Therefore, such link failures will entail a process of route maintenance to initiate the route recovery process to discover new links (Rajagopalan & Dahlstrom, 2012). However, such a process will unduly introduce additional routing overheads and delays (Yuan, Ding & Zhang, 2010). Premised in this context, this research was carried out to address such issues by focusing on the appropriate techniques to help improve the performance of the route discovery process of AODV in MANETs and to maintain the connections through which network services could be delivered to users without any disruptions.

To date, many attempts have been made to solve the flooding issue (Zarei et al., 2008; Geetha & Umarani, 2011; Zhao et al., 2015) during the route discovery cycle. Admittedly, almost all the studies were only dedicated to improving AODV by focusing only on the routing information of one-hop neighbors. In addition, such studies only focused on several main parameters, such as packet delivery ratio, end-to-end delay, and routing overhead, without paying greater emphasis on other critical performance parameters, such as the throughput, the number of RREQs sent through the network, and the data that are discarded during the route discovery cycle. Hence, this study was carried out to address the lack of focus on these parameters with the proposed new method, called Less Flooding AODV (LF-AODV), which took into account not only the routing information of one-hop neighbors in route discovery process but also the routing information of two-hop neighbors.

In order to maximize the network lifetime, several researchers (Xu & Li, 2014; Hamad et al., 2011; Srinivasan & Kamalakkannan, 2013) have proposed a number of schemes or methods to improve energy consumption. Evidently, a majority of the studies reported in the literature are largely focused on link lifetime and energy information as the routing metrics to improve the route selection mechanisms of the AODV protocol. However, the methods employed only considered the link lifetime and residual energy level of one-hop neighbors. In contrast, the routing mechanism proposed in this study, called Route Stability Aware (RSA), would consider the level of link lifetime and residual energy of both one-hop and two-hop neighbor nodes before broadcasting the control packets. Admittedly, this study represents the first attempt at introducing link life time and nodes' residual energy for one-hop and two-hop neighbor as a means to enhance the route discovery process.

1.3 Research Objectives

In view of the problem statements, this research was carried out with the main objective to improve the performance of the route discovery process of AODV routing protocol in mobile ad-hoc networks (MANETs). The specific objectives of this research are as follows:

1. To investigate the performance of the route discovery process of AODV in mobile ad-hoc networks (MANETs) based on several different scenarios.

2. To design and propose a less flooding AODV (LF-AODV) method that could reduce the number of route request (RREQ) packets transmitted during the route discovery cycle.

3. To design and propose a route stability aware (RSA) method that could reduce the occurrence of link failures and route breakages during the route discovery cycle.

1.4 Research Questions

To help achieve the specific objectives of this study, four research questions were formulated as follows:

1. Would the use of the AODV protocol improve the performance of MANETs during the route discovery cycle?

2. How does the proposed method help reduce the number of route request (RREQ) packets transmitted during the route discovery cycle?

3. How does the proposed method help reduce the occurrence of link failures and route breakages during the route discovery cycle?

4. Would the proposed routing protocol be able to reduce the cost of re-initiation of route request (RREQ) packets to a minimum such as to help extend the network lifetime?

1.5 Research Scope

This research was conducted to investigate the performance of route discovery process of AODV protocol in a small-sized network with medium-density of nodes in various scenarios based on several important network elements, such as the number of nodes, mobility speed, and network load in relation to the routing overheads and delays produced. The study was conducted using the NS-2 simulator (Issariyakul & Hossain, 2009) running on the Window operating system platform. In the experiments, the numbers of nodes were set to 10 to 100 mobile nodes, which were randomly propagated in an area measuring 600 meters by 600 meters. The random waypoint (RWP), which captured the movements of independent nodes in the simulated area, was used to simulate node mobility. The experimental results were then compared with those of the OLSR protocol as a benchmark for the AODV's performance.

In addition, another aim of this research was to propose a practical solution with which AODV would be able to reduce the number of redundant packets and broken communication routes due to flooding and topological changes occurring during the route discovery process. More specifically, the imperative of the study was to focus on reducing the number of route request (RREQ) packets transmitted during the route discovery cycle and the occurrence of link failures and route breakages during the route discovery cycle, minimizing overheads and delays produced as well as maximizing the lifetime of network nodes.

1.6 Research Contributions

It is expected that the performance results of the route discovery process of the AODV protocol based on different scenarios can help shed a greater insight into the understanding of the current practice. More specifically, the proposed LF-AODV method is expected to help minimize the number of redundant RREQs, which in turn help reduce routing overheads. As such, this new protocol can be adapted as a method for the route discovery process in MANETs. Likewise, the proposed RSA method is also expected to help reduce the frequency of route breakages, which in turn help optimize the network lifetime performance during the route discovery process in MANETs. Therefore, this new protocol can also be adapted as another method for the route discovery process in MANETs. The main contributions of this study are as follows:

1. The results of the performance of the route discovery process of AODV based on several different scenarios in MANETs.

2. The development of less-flooding AODV (LF-AODV) method that can reduce the number of route request (RREQ) packets transmitted during the route discovery cycle in MANETs.

3. The development of route stability aware (RSA) method that can reduce the occurrence of link failures and route breakages during the route discovery cycle in MANETs.

In addition, the findings of the study will provide new insights into the understanding of the current practice, benefiting several stakeholders, such as researchers, mobile service providers, and end users. New knowledge and insights gained from this research will certainly benefit researchers who are interested to undertake similar research. Particularly, the methodology and principles used in this research can serve as important guidelines with which future studies can be successfully pursued. From a practical standpoint, the improved routing method can be utilized by mobile service providers to improve their existing products or services through more reliable, stable communication networks.

Having gained relevant information, mobile service providers can strategize their business planning in ways that can help improve their products or services. With such improvements, they can further sustain and increase their market share. Finally, the end users or customers will be able to gain better services from mobile service providers with improved network communication. Effectively, high customer satisfaction can be realized with efficient, effective mobile networks, enabling users to use a host of mobile applications anywhere, anytime more reliably.

1.7 Organization of the Thesis

This thesis consists of five chapters that discuss the background of the study, review of literature, research methodology, research findings, and conclusions as follows:

Chapter 1:

The first chapter introduces the main elements of the thesis. Specifically, it elaborates the research background, problem statement, research objectives, research questions, research scope, and research contributions. In addition, this first chapter outlines the organization of the remaining chapters of the thesis.

Chapter 2:

The second chapter discusses the review of the current literature related to mobile ad hoc networks and routing protocols. In particular, the second chapter discusses the features and capabilities of a number of widely known routing protocols for MANETs. In particular, the discussion on the AODV routing protocol is given strong emphasis in view of its unique capabilities in improving the route discovery process in MANETs. The second chapter also elaborates the common problems encountered in the route discovery process with the use of AODV. Furthermore, the second chapter discusses several previous works that focus on issues involving broadcast flooding and topological changes during the route discovery cycle. In addition, this chapter discusses the elements of research methodologies used for this study.

Chapter 3:

The third chapter provides a detailed discussion of the research methodology used for the study. Particularly, the discussion focuses on the simulation modeling and parameters setting used to measure and test the network performance of the proposed design of the LF-AODV and RSA methods.

Chapter 4:

The fourth chapter discusses the results of the network performance analysis based on the research objectives as outlined in Chapter 1. In particular, the fourth chapter discusses the experimental results of the AODV routing protocol based on several different scenarios (node density, node mobility speed, and routing load). This chapter also discusses the experimental results of the LF-AODV and RSA methods.

Chapter 5:

The fifth chapter summarizes the main research findings of the study. In addition, this chapter highlights the limitations of the present study and outlines several potential directions in which future research should take.

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